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研　究　主　論　文　抄　録

論文題目

Fundamental study on fracture toughness and fracture mechanism of rocks
（岩石の破壊靱性と破壊メカニズムに関する研究）

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主論文要旨

In order to investigate the influence of several factors on the mode-I fracture toughness and fracture behavior of rocks, fracture toughness tests were conducted under various conditions of specimen shape and size, loading rate, confining pressure and water vapor pressure. The influence of not only these extrinsic factors but also intrinsic one, namely microstructure of rocks, was also investigated to understand the fracture toughness and fracture mechanism of rocks.

This dissertation consists of eight chapters. In chapter 1, the introduction was described as well as the objective and outline of this dissertation. In chapter 2, a basic knowledge of fracture mechanics and fracture toughness of rocks were summarized. Moreover, evaluation methods for the fracture toughness and the influence of several factors on the fracture toughness were reviewed in this section.

In chapter 3, the effect of the specimen shape and size on the mode-I fracture toughness of rock was investigated. Three fracture toughness tests including semi-circular bend (SCB), chevron bend (CB) and straight notched disk bending (SNDB) tests were conducted using different types of the specimen shape of Kimachi sandstone. As a result, the fracture toughness evaluated by the SCB tests was almost same as that evaluated by the CB tests and higher than that evaluated by the SNDB tests. The SCB tests using various sizes of the specimens were also conducted. The obtained fracture toughness had a size effect in the SCB test. The fracture toughness increased with increasing the specimen size and converged on a certain constant value in a range larger than approximately 70 mm of the specimen radius.

In chapter 4, the influence of the loading rate on the mode-I fracture toughness of the sandstone was discussed on the SCB test. A series of tests under a wide range of the loading rate from 10^{-3} to 10^{6} mm/min were conducted. A servo-controlled testing

machine and a split Hopkinson pressure bar were used as a loading system for the loading rate from 10^{-3} to 10^{3} mm/min as static loading, and from 10^{5} to 10^{6} mm/min as dynamic loading, respectively. In the experimental results, it was shown that the fracture toughness evaluated in the dynamic loading was higher than that in the static one. Each of the fracture toughness was dependent on the loading rate and increased with increasing the loading rate.

In chapter 5, the SCB tests under confining pressure ranging from 0 to 10 MPa were conducted using the same sandstone in order to investigate the influence of the confining pressure on the mode-I fracture toughness of the rock. The finite element analysis of the SCB tests under several confining pressure conditions was also performed. Based on the numerical results, the fracture toughness of the rock under confining pressure was estimated from the experimental results. It was found that the fracture toughness was dependent on the confining pressure and increased with increasing the confining pressure.

In chapter 6, the influence of the water vapor pressure on the mode-I fracture toughness of several rock types, Kimachi sandstone, African granodiorite and Korean granite, was investigated. The SCB tests were conducted under various water vapor pressures from 10^{-2} to 10^{3} Pa. Observation of thin sections of these rocks was also performed to investigate the microstructures of the rocks. The test results showed that the fracture toughness of the sandstone was hardly dependent on the water vapor pressure. On the other hand, the fracture toughness of the granodiorite and granite was dependent on the water vapor pressure and decreased with increasing the water vapor pressure. It was found that the degree of the dependence was sensitive to microcrack distributions of the rocks.

In chapter 7, the influence of the microstructures of rocks on the anisotropy of the mode-I fracture toughness was discussed. The SCB tests using two types of the specimens having the different directions were conducted in the same rock types used in the experiments under water vapor pressure. As a result, the rocks exhibited the anisotropy of the fracture toughness in varying degrees. There was a relatively small degree of the fracture toughness anisotropy in Kimachi sandstone. On the other hand, in African granodiorite and Korean granite, the fracture toughness in the direction in that many microcracks were oriented was higher than that in the other direction. Based on detailed observations of fractures within fractured specimens visualized by X-ray CT scanner after the experiments, it was concluded that grain distributions induced the anisotropy of the fracture toughness in these crystalline rocks. Then, numerical simulations of the SCB test were conducted by distinct element method, considering the anisotropy of the microstructure of rocks. Putting the experimental and numerical results together, it was made clear that the grain distribution influences the anisotropy of the fracture toughness and fracture behavior of rocks.

In chapter 8, the results obtained from each chapter were summarized.